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COPERNICUS, therefore, did not advance Astronomy in the least; it merely showed that it was impossible to calculate the motions of the planets without having the origin of the co-ordinates in the centre of the earth. But of proofs of the physical truth of his system, COPERNICUS had given none, and could give none; and, though there can hardly be any doubt that he himself believed in the reality of the earth's motion, it is extremely difficult to say of most of his so-called followers whether they had any faith in that motion or merely preferred it for geometrical reasons.

Though against his own wishes TYCHO BRAHE has contributed very much to the success of the Copernican system, for the numerous and most accurate observations made by the Danish astronomer on his little island in the Sound between Seeland and Scania are the source, from which JOHANNES KEPLER deduced his renowned laws. "ARCHIMEDES of old had said, 'Give me a place to stand on, and I will move the world?' TYCHO BRAHE had given KEPLER the place to stand on, and KEPLER did move the world!" On his death-bed the great observator several times exclaimed:

"Ne frustra vixisse videar!"

His death occurred on the 24th day of October, 1601. The future will bear witness that he did not live in vain.

As his countryman, I allow myself to congratulate the author, thanking him heartily for his excellent work.

ODDER, DENMARK, 1891, April 15.

THE PERIOD OF THE ROTATION OF THE SUN NEAR THE POLES, AS DERIVED FROM THE CORONAS OF 1878 AND 1889.

BY PROFESSOR FRANK H. BIGELOW.

In the *American Journal of Science* for November, 1890, the formulae for discussing coronas, and the results obtained by a study of the photographs taken during the eclipse of July 29, 1878, were presented and fully explained. In this paper the conclusions and the deductions to be derived from the coronas of Jan. 1, 1889, and Dec. 22, 1889, are added, with the period of the rotation of the Sun as found from these three coronas.

The following tables summarize the data in the briefest form.

Column 1 shows the number of rays which were measured on the photographs.

Columns 2 and 3 give the polar co-ordinates of each point of the ray, at least three points being measured, the first near the disk, the second at a mid point, and the third near the visible extremity of the ray. The axis of reference was taken by setting the thread on the projected ray whose trace had a radial direction from the centre of the disk.

The column α gives the angle between the plane of the ray and the plane of the disk, which is taken as the plane passing through the centre of the sun at right angles to the line of sight. Strictly, the planes of the coronal rays intersect in an axis which does not coincide with the plane of the disk, and a slight error is admitted by assuming provisionally that it does. It is one object of our investigation to discover the angular distance between the pole of the corona and its trace.

Now,
$$\sec^2\alpha = \frac{X_2^{\frac{4}{3}} Y_1^2 - Y_2^2 X_1^{\frac{4}{3}}}{X_1^{\frac{4}{3}} X_2^2 - X_2^{\frac{4}{3}} X_1^2}$$

where $x_1 = r_1 \sin\theta_1$ $y_1 = r_1 \cos\theta_1$ for the first point,

and $x_2 = r_2 \sin\theta_2$ $y_2 = r_2 \cos\theta_2$ for the second point,

Using all values of $(r\,.\,\theta)$ we obtain three values of α. The adopted value is given in the table.

The column θ_0 gives the angle from the coronal pole at which each ray springs from the surface of the sun, in the direction α from the plane of the disk, the results being computed for each point of the ray. If the angle α is inaccurate the values of θ_0 will progress in one direction, and hence a check is obtained for the adopted α. At this step a second computation is frequently required. The outstanding irregularities arise from the difficulty of setting the measured points of the photograph on the true stream lines of the corona.

Then,
$$\sin^2\theta_0 = \frac{x^2 \sec^2\alpha}{(x^2 \sec^2\alpha + y^2)^{\frac{3}{2}}}$$

where x and y have three values in order. The columns r', θ' give the co-ordinates in space of the point whose projected position we see on the photograph. We present only that corresponding to the first point of the ray; the others could be found by extending the computation.

Next,
$$r'^2 = x_1^2 \sec^2 \alpha + y_1^2$$
$$\sin^2 \theta' = r' \sin^2 \theta_0.$$

This will give the position of the extremities of the rays as seen from the center of the sun, by taking the co-ordinates (r_n, θ_n), and they may be used in considering the relations of these positions to the sun spots.

The column p gives the angle at the center of the sun from a point (r', θ') to the pole of the disk, that is to the trace of the true coronal pole, θ' being the angle to the coronal pole itself. If p is greater than θ', then the pole of the corona is on the earth side of the disk, since it is evident that the rays that are photographed are those which lie on the earthward side of the sun,

$$\tan p = \tan \theta_1 \sec \alpha.$$

Column c gives the angular distance of the coronal pole from its projection on the plane of the disk.

$$A = 90 - \alpha$$
$$\sin B = \sin p \cos \alpha \operatorname{cosec} \theta'$$
$$\tan \tfrac{1}{2} c = \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)} \cdot \tan \tfrac{1}{2}(p + \theta').$$

Each quadrant is computed independently, and the mean of the two quadrants about each pole, North or South, will eliminate the error of selecting the position of the coronal pole, at the beginning of the measures.

To recapitulate, columns log r_n, θ_n, give the co-ordinates of the measured points, $n = 1 \cdot 2 \cdot 3 \ldots$, as projected; the columns α, θ_0, give the angular co-ordinates of the point on the sun's surface from which the ray springs; the columns log r', θ', the co-ordinates of the point in space, projected in the picture; the columns θ', p, c, the sides of the spherical triangle formed by point on the ray, the pole of the corona, and the trace on the plane of the disk.

By means of the resulting data an accurate model of the corona can be made.

Corona of July 29, 1878.—N. E. Quadrant.

Ray.	log r_n	θ_n	a	θ_o	log r'	θ'	p	c
		° ′	°	° ′		° ′	° ′	° ′
1	0.00000	3 40	89 0	. . . . .	0.21388	39 20	40 55	1 35.0
	0.09225	0 52		30 40				
	0.17499	1 30		28 35				
2	0.00000	0 2	88 50	. . . . .				
	0.10804	3 22		28 32				
	0.18808	6 30		. . . . .				
3	0.00000	3 38	85	28 43	0.09159	34 45	36 4	1 20.2
	0.10959	7 6		32 55				
	0.16603	8 56		30 59				
4	0.00000	6 50	81	31 8	0.09717	36 3	37 27	1 24.5
	0.10959	13 21		33 39				
	0.17587	17 42		30 32				
5	0.00000	11 35	75	32 41	0.09678	37 19	38 23	1 5.3
	0.10284	16 27		33 17				
	0.17940	21 28		31 32				
6	0.00000	19 17	64	33 25	0.08194	38 41	38 36	−0 5.5
	0.12328	26 00		33 18				
	0.13800	30 31		34 34				
7	0.00000	28 31	49	36 0	0.05725	38 46	39 38	1 9.0
	0.11573	36 48		36 23				
	0.18419	41 18		35 16				
8	. . . .	. . . . .						
	0.09757	48 20	24	42 25	0.12036	49 48	50 53	2 46.3
	0.17543	56 9		42 23				
	0.25638	61 40		40 16				
				Mean.				1 9.4

July 29, 1878.—N. W. Quadrant.

1	0.00330	11 15	75	33 5	0.09564	35 15	37 33	2 24.0
	0.09757	12 0		30 17				
	0.16376	14 30		30 2				
2	0.00000	13 17	65	28 2	0.05720	29 20	29 11	−0 1.6
	0.10284	15 30		27 41				
	0.16694	16 44		26 11				
3	0.00000	15 20	73	36 30	0.12128	40 52	43 10	+2 24.5
	0.10284	19 1		34 5				
	0.18593	23 1		32 5				
4	0.00000	18 58	68	34 52	0.10837	38 49	42 32	+4 2.6
	0.11522	24 5		33 30				
	0.18549	29 24		32 26				
5	0.00000	22 42	59	34 24	0.07499	37 8	39 5	+2 17.0
	0 10804	30 14		35 0				
	0.19236	39 22		34 23				
	0.23837	43 26		33 5				
	0.28825	47 34		31 29				
6	0.10284	47 35	30	41 55	0.13909	51 9	51 39	+1 0.5
	0.21152	61 14		41 58				
	0.27012	69 28		40 49				
				Mean.				2 0.3

Corona of July 29, 1878.—S. W. Quadrant.

Ray.	log r_n	θ_n	α	θ_0	log r'	θ'	p	c
		° ′	°	° ′		° ′	° ′	° ′
1	0.00000	2 39	87	35 0	0.12501	38 35	41 29	2 51.3
	0.10388	2 56		31 41				
	0.16148	3 20		30 21				
2	9.99667	4 21	84	29 22	0.08771	34 9	36 3	1 58.1
	0.11062	6 51		31 23				
	0.17940	8 32		30 44				
3	0.01000	6 50	82	33 59	0.11735	37 51	40 44	2 56.6
	0.11062	8 37		32 26				
	0.17808	11 16		30 50				
4	0.00000	9 0	78	30 17	0.09399	34 36	37 18	2 45.3
	0.08848	11 37		31 25				
	0.16603	13 58		30 14				
5	0.00000	13 1	75	33 51	0.11606	40 10	41 46	1 12.3
	0.08685	20 43		35 51				
	0.14375	20 25		33 20				
6	0.00330	25 12	59	36 33	0.09166	41 6	42 25	1 8.9
	0.10804	33 37		36 35				
	0.16240	39 1		35 41				
7	0.09225	39 2	48	38 59	0.17873	50 45	50 28	-0 23.7
	0.15131	47 28		38 57				
8	0.11826	47 30	33	41 6	0.16308	52 11	52 27	0 30.6
	0.18808	55 58		41 7				
	0.23876	62 52		40 30				
				Mean	.....	.....	.....	1 45.0

July 29, 1878.—S. E. Quadrant.

1	0.00000	0 49	88 50	31 41	0.08655	38 35	41 29	2 51.3
	0.09757	1 55		33 25				
	0.17053	2 20		29 28				
2	0.00066	1 7	88 40	30 28	0.08100	34 9	36 3	1 58.1
	0.08139	3 32		32 34				
	0.14755	7 40		.....				
3	0.00208	9 7	79	34 25	0.11272	37 51	40 44	2 56.6
	0.08249	14 40		34 59				
	0.15224	18 30		31 48				
4	0.00066	14 22	71	33 45	0.09148	34 36	37 18	2 45.5
	0.10804	20 48		34 1				
	0.19448	28 32		31 38				
5	0.00133	18 14	66	34 1	0.08849	40 10	41 46	1 12.3
	0.11573	25 51		34 19				
	0.17053	31 4		33 25				
6	0.00066	20 42	62	34 52	0.08014	41 6	42 25	1 8.9
	0.13800	31 32		34 54				
	0.21718	37 50		32 38				
7	0.00199	31 14	42	35 8	0.04482	50 45	50 28	-0 23.7
	0.11826	37 57		35 13				
	0.19150	43 28		35 11				
8	9.00723	34 38	40	39 7	0.05173	52 11	52 27	0 30.6
	0.11927	43 34		39 11				
	0.19065	50 17		38 39				
	0.25120	57 26		37 26				
				Mean	.....	.....	.....	1 45.0

Corona of January 1, 1889.—N. E. Quadrant.

Ray.	log r_n	θ_n	α	θ_0	log r'	θ'	p	c
		° ′	° ′	° ′		° ′	° ′	° ′
1	0.08104	1 43	88 30	37 36	0 18274	44 55	48 52	3 56.9
	0.09463	2 0		33 46				
	0.18056	2 53		33 20				
2	0.00362	2 50	85	27 19	0.06379	30 51	29 35	−1 14.9
	0.12208	4 20		29 44				
	0.20126	5 3		28 18				
3	0.00207	5 51	78	24 45	0.04701	26 7	26 14	0 46.6
	0.09919	6 47		24 28				
	0.18566	8 23		24 45				
4	0 20618	11 16	55	18 38	0.02246	18 31	19 9	0
	0.11815	12 27		17 51				
	0.18499	13 24		17 35				
5	0.00460	16 35	64	31 17	0.06709	34 3	34 11	0
	0.10084	19 53		30 53				
	0.18397	22 31		31 29				
6	0.00618	29 17	52	38 0	0.07799	42 7	42 20	0 1.5
	0.68960	36 56		38 25				
	0.16098	43 12		37 3				
7	0.00618	42 3	25	43 11	0.02639	44 31	44 44	0 30.8
	0.10411	49 45		43 5				
	0.17228	55 33		42 17				
				Mean................................				0 34.4

January 1, 1889.—N. W. Quadrant.

1	0.00207	2 40	86	30 22	0.08166	33 56	33 44	0 19.3
	0.07763	3 28		31 28				
	0.17158	4 19		29 49				
2	0.00259	5 50	81	30 1	0.07748	32 36	33 9	0 32.8
	0.10817	7 54		30 34				
	0.17088	8 40		27 59				
3	0.00104	6 32	81	32 7	0.09140	36 10	36 12	4 40.4
	0.08960	9 15		33 1				
	0.16490	11 25		31 7				
4	0.00618	9 24	77	32 7	0.09430	36 33	36 20	−0 13.2
	0.10736	15 48		33 48				
	0.18397	18 48		31 0				
5	0.00464	13 17	72	33 7	0.16095	41 14	37 22	−4 3.1
	0.09588	20 0		34 31				
	0.17988	25 8		31 57				
6	0.09170	27 10	58	34 14	0.17982	41 43	44 5	2 49.7
	0.17018	36 17		34 36				
	0.22351	43 10		33 33				
	0.28895	48 14		31 17				
	0.32400	50 59		30 4				
				Mean................................				0 34.6

Corona of January 1, 1889.—S. W. Quadrant.

Ray.	log r_n	θ_n	a	θ_o	log r'	θ'	p	c
		° ′	° ′	° ′		° ′	° ′	° ′
1	0.99845	2 19	86 50	32 8	0.06585	34 41	31 11	−3 29.1
	0.07676	3 3		32 39				
	0.17018	4 12		30 42				
2	9.99897	5 27	82	31 1	0.08066	33 4	34 26	0 12.2
	0.10411	6 10		29 0				
	0.17018	7 57		29 27				
3	0.00104	6 59	80	31 29	0.08551	35 16	35 12	0
	0.10248	9 57		32 16				
	0.15775	11 6		30 53				
4	9.99845	11 26	72	30 27	0.06716	32 54	33 12	0 18.9
	0.10615	14 50		30 41				
	0.17367	16 25		29 25				
5	9.99897	14 9	72	34 27	0.09638	39 5	39 13	0 7.9
	0.05767	17 51		35 10				
	0.12984	21 17		33 26				
6	0.00104	22 23	46	29 25	0.03243	30 34	30 40	0 8.5
	0.10817	26 38		29 29				
	0.17816	29 33		29 5				
7	0.00104	28 21	53	37 49	0.07365	40 36	41 53	1 37.8
	0.07676	34 42		35 53				
	0.15739	40 41		36 28				
8	9.99479	39 13	36	42 55	0.03261	44 46	45 15	0 50.5
	0.07676	46 41		43 11				
	0.17954	55 25		42 2				
			Mean.					−0 1.7

January 1, 1889.—S. E. Quadrant.

1	0.00104	1 12	88 20	31 44	0.09168	35 55	35 46
	0.08195	1 40		32 40			
	0.15231	2 4		31 11			
2	9.99845	3 44	83 30	27 47	0.05970	29 31	29 58
	8.10614	4 26		27 4			
	0.17713	5 23		27 17			
3	9.99845	6 23	80	29 56	0.07117	32 52	32 48
	0.09795	8 13		30 14			
	0.16312	9 57		29 51			
4	9.99845	10 3	76	32 24	0.08502	36 4	36 14
	0.10061	14 29		33 8			
	0.17644	18 15		31 17			
5	9.99949	15 15	69	33 23	0.08308	37 50	37 16
	0.08960	20 18		33 55			
	0.16737	26 40		32 46			
6	0.05994	23 26	61	33 24	0.15011	41 24	40 29
	0.12675	29 37		34 50			
	0.20709	37 45		33 10			
7	0.04055	21 2	65	34 53	0.14927	42 11	43 24
	0.12522	31 15		35 31			
	0.20061	40 57		32 55			
8	0.05767	31 37	58	37 49	0.17342	47 11	49 17
	0.12598	39 57		37 17			
	0.20061	47 4		35 30			
			Mean.				0 34.6

Corona of December 22, 1889.—N. E. Quadrant.

Ray.	log r_n	θ_n	α	θ_o	log r'	θ'	p	c
		° ′	° ′	° ′		° ′	° ′	° ′
1	0.00000	1 58	87 30	33 16	0.10477	34 49	38 13	3 15.8
	0.08579	2 5		30 22				
	0.16769	2 3		27 35				
2	0.03820	4 5	82 30	25 31	0.09392	28 43	28 40	0 8.4
	0.11484	4 46		25 42				
	0.16769	5 11		25 27				
3	0.03668	7 52	79	30 33	0.12379	35 53	35 55	3 47.5
	0.08905	9 23		31 9				
	0.14921	10 22		29 57				
4	0.05612	13 2	68	27 25	0.11502	31 28	31 43	0 16.4
	0.10580	14 25		27 32				
	0.16085	15 20		26 41				
5	0.05465	13 20	71	30 15	0.13512	36 3	36 3	0 0
	0.09337	14 32		30 12				
	0.14087	16 39		30 17				
6	0.04336	15 57	68	31 38	0.12592	35 39	37 20	1 48.4
	0.09471	18 8		31 42				
	0.14207	20 6		31 9				
7	0.04124	17 27	65	31 28	0.11640	36 28	36 28	0 0
	0.08579	19 30		31 39				
	0.14565	21 56		31 1				
8	0.04606	42 36	48	28 43	0.08240	31 53	31 53	0 0
	0.10711	24 51		28 37				
	0.14684	26 52		28 48				
9	0.04666	25 42	60	35 59	0.14380	43 48	43 54	0 3.9
	0.09122	29 25		36 0				
	0.13724	34 40		35 47				
10	0.04815	31 56	54	38 7	0.14050	46 23	46 41	0 21.5
	0.11228	39 39		38 24				
	0.16428	46 28		37 31				
			Mean................................					0 58.2

Corona of December 22, 1889.—N. W. Quadrant.

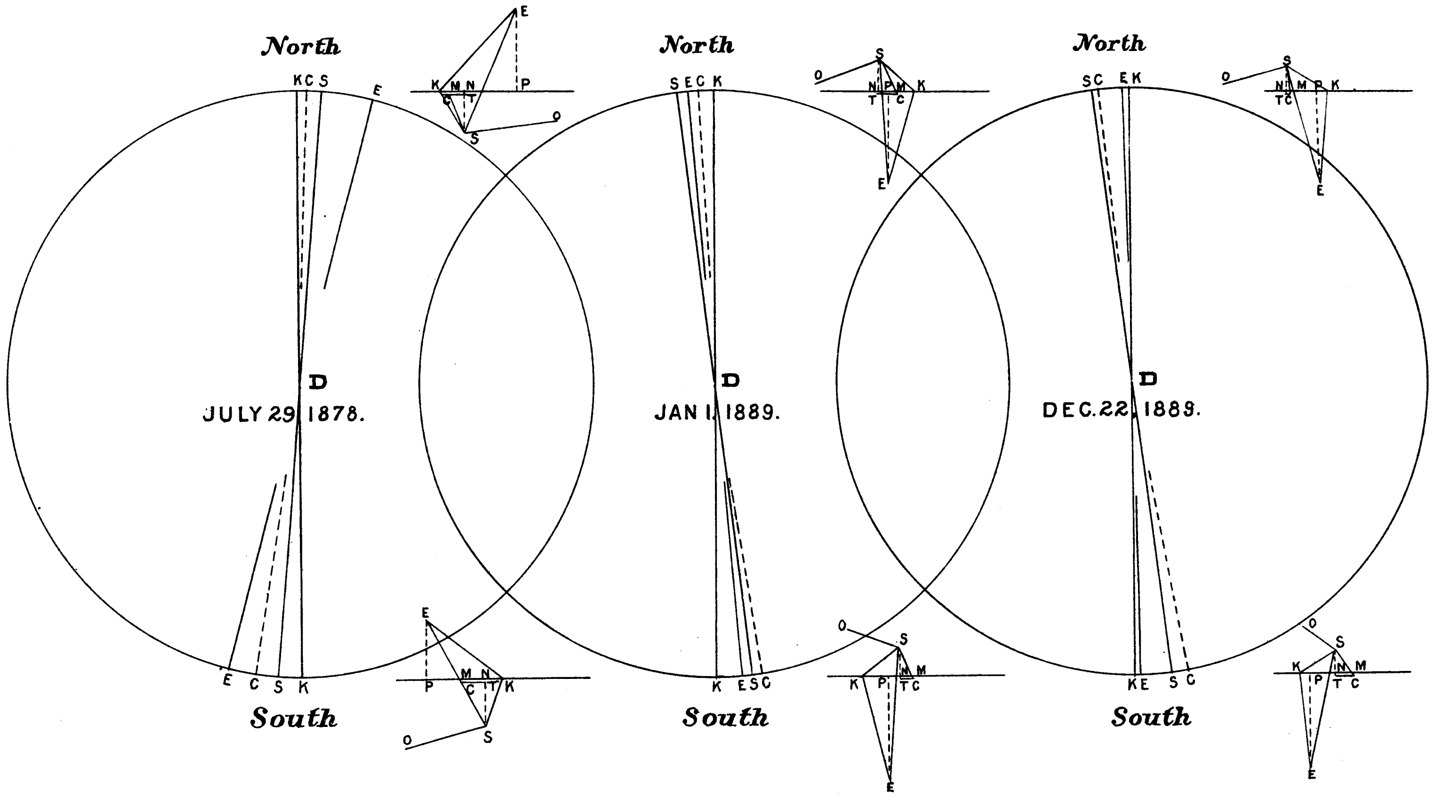
Ray,	log r_n	θ_n	α	θ_o	log r'	θ'	p	c
		° ′	° ′	° ′		° ′	° ′	° ′
1	0.02740	3 7	85	28 33	0.09832	32 42	32 0	−0 36.7
	0.08001	3 46		29 27				
	0.13724	4 7		28 33				
2	0.04185	5 20	80	25 7	0.09510	28 21	28 16	−0 6.2
	0.09256	5 47		24 58				
	0.13797	6 31		25 28				
3	0.04275	8 39	76 50	29 0	0.11787	33 44	33 8	−0 3.8
	0.08029	9 23		29 0				
	0.13966	10 53		28 59				
4	0.04215	14 7	63	26 0	0.08695	29 0	28 59	0 8.5
	0.09391	15 23		25 59				
	0.14014	16 48		26 4				
5	0.04426	18 59	67	34 1	0.14458	41 15	41 22	0 6.8
	0.08589	22 0		34 22				
	0.13408	24 33		33 24				
6	0.05318	22 39	62	34 13	0.14475	41 31	41 38	0 7.6
	0.09658	26 4		34 32				
	0.15507	30 6		33 40				
7	0.04426	27 55	50	34 23	0.10312	39 23	39 30	0 0
	0.08987	30 49		34 31				
	0.14494	34 4		34 1				
8	0.04576	37 23	36	38 22	0.08437	43 4	43 22	0 30.1
	0.11330	42 45		38 43				
	0.18324	47 27		37 37				
9	0.05612	42 44	8	39 39	0.05809	42 36	43 1	4 7.5
	0.13064	47 47		39 40				
	0.20495	51 34		38 33				
			Mean	....	....	....	....	0 28.5

Corona of December 22, 1889.—S. W. Quadrant.

Ray.	log r_n	θ_n	α	θ_o	log r'	θ'	p	c
		° ′	° ′	° ′		° ′	° ′	° ′
1	0.03052	2 19	86 50	30 50	0.12340	36 43	36 13	−0 26.9
	0.06766	2 52		32 21				
	0.14207	3 15		30 33				
2	0.05612	5 52	81	28 9	0.13173	32 17	33 18	1 16.7
	0.10712	6 10		27 12				
	0.14327	6 26		26 37				
3	0.03361	8 20	76 30	28 14	0.09965	32 3	32 6	0 2.7
	0.07751	9 5		28 11				
	0.14850	10 48		28 18				
4	0.03973	13 48	65	26 56	0.09021	30 13	30 10	−0 2.8
	0.09711	15 33		27 15				
	0.14803	16 42		26 46				
5	0.06394	20 12	58	28 58	0.12280	34 9	34 46	0 42.7
	0.10266	21 50		29 2				
	0.14921	23 42		29 31				
6	0.05318	25 8	58	34 33	0.13566	41 21	41 31	0 11.6
	0.10056	28 52		34 50				
	0.16314	32 56		33 52				
7	0.07751	31 47	54	36 40	0.16922	46 27	46 27	0 0
	0.12668	38 2		36 38				
	0.18802	44 13		36 34				
8	0.06623	32 23	54	37 34	0.16047	46 44	47 11	0 34.5
	0.10711	37 32		37 55				
	0.16085	45 27		37 25				
	0.20661	51 25		36 5				
				Mean..................................				0 1.8

December 22, 1889.—S. E. Quadrant.

1	0.03515	3 6	86	31 35	0.13695	37 43	37 50	0 11.1
	0.09658	4 11		31 30				
	0.14992	5 7		31 26				
2	0.07050	3 34	86	32 4	0.19716	41 35	41 47	0 12.7
	0.09604	5 2		33 39				
	0.15716	8 13		30 4				
3	0.03576	7 13	82	31 46	0.18696	40 39	38 3	−2 37.6
	0.09938	7 37		31 53				
	0.14087	8 54		31 24				
4	0.05465	10 3	77	31 16	0.15278	38 11	38 14	0 3.5
	0.11099	11 55		31 19				
	0.14850	13 35		31 6				
5	0.03973	11 59	75	32 35	0.14215	38 55	39 21	0 28.2
	0.10970	15 28		32 48				
	0.17996	19 46		31 19				
6	0.05465	15 9	72	33 4	0.16300	40 11	41 14	1 6.1
	0.11099	19 16		33 31				
	0.16995	23 35		32 12				
	0.21683	27 23		30 33				
7	0.09256	22 53	62	33 56	0.18559	42 55	41 57	−1 0.9
	0.13773	26 38		33 41				
	0.18759	29 40		32 29				
				Mean..................................				−0 13.8



THE RELATIVE POSITIONS OF THE POLES OF THE ECLIPTIC, CELESTIAL EQUATOR, SUN'S AXIS, AND AXIS OF THE CORONA, FOR THE ECLIPSES OF JULY 29.1878. JAN.1,1889. DEC.22,1889.

I should like to direct attention to the comparative smoothness of the results for the Corona of Dec. 22, 1889, as showing what can be done by this analysis. The improvement arises from the good size of the photograph, and the practice in measuring up such plates, as well as from increased judgment in the application of the formulæ. In some parts there is little to be desired, unless, perchance, an attempt be made to carry the problem further in its physical aspects.

If I is the inclination of the Sun's Equator to the Ecliptic, $7^\circ\ 15'$,

w, the inclination of the Earth's Equator to the Ecliptic, about $23^\circ\ 27'.3$.

N, the longitude of the Node of the Sun's Equator, 74°.

$\odot$, the longitude of the Sun at the Epoch of the Eclipse,

D, the center of the Sun's disk, and the direction for position angles positive towards the West, we have,

$$H = SDK;\ \tan H = \tan I \cos (\odot - N),$$
$$G = EDK;\ \tan G = \tan w \cos \odot.$$

If the projection of E is P,
“ “ S is N,
“ “ C is M,
“ “ K is K,

we have the following formulæ:

$$PM = PN + NM, \qquad CT = MN \cdot \cos CM,$$
$$NKS = \odot - N, \qquad \cos CS = \cos CT \cos ST,$$
$$\tan NK = \cos NKS \tan KS, \qquad \cos CST = \sin ST \cos CT,$$
$$\sin SN = \sin NKS \sin KS, \qquad \cos NSK = \sin NKS \cos NK,$$
$$ST = SN + MC, \qquad CSK = NSK - CST,$$

$KOS = 90^\circ$; O, the direction of the Node N.

$OS\acute{C} = OSK - CSK$, the longitude of the Coronal Pole, on the plane of the Sun's Equator from the Node.

$90 - CS$, the latitude of the Coronal Pole from the Sun's Equator.

	JULY 29, 1878.		JAN. 1, 1889.		DEC. 22, 1889.	
	N.	S.	N.	S.	N.	S.
	° ′	° ′	° ′	° ′	° ′	° ′
I (K S).....	7 15	7 15	7 15	7 15	7 15	7 15
ω (K E)....	23 27.4		23 27.2		23 27.2	
N..........	74		74		74	
⊙..........	126 10.9		281 20.6		270 54.2	
H (K D S)..	+ 4 27.6	− 4 27.6	− 6 26.8	+ 6 26.8	− 6 56.4	+ 6 56.4
G (E D K)..	− 14 22.1	+ 14 22.1	+ 4 52.6	− 4 52.6	+ 0 23.5	− 0 23.5
G+H (E D S)	− 9 54.5	+ 9 54.5	− 1 34.2	+ 1 34.2	− 6 32.9	+ 6 32.9
N M.......	− 2 30	− 4 30	+ 4 0	+ 2 0	+ 1 0	+ 3 30
M C.......	+ 1 35	+ 1 28	+ 0 35	+ 0 17	+ 0 43	+ 0 2
P M.......	− 12 24.5	+ 5 24.5	+ 2 25.8	+ 3 34.2	− 5 32.9	+ 10 2.9
N K.......	4 27.6	4 27.6	6 26.8	6 26.8	6 56.4	6 56.4
S N.......	5 41.6	5 41.6	3 19.4	3 19.4	2 6.2	2 6.2
C S........	4 48	6 11	5 35	3 38	3 0	3 58
C S T......	31 21	46 53	45 45	33 22	19 32	61 55
N S K......	38 3	38 3	62 9	62 9	73 13	73 13
K S C......	6 42	84 56	16 24	95 31	53 41	135 8
K S O......	90	270	90	270	90	270
O S C......	83 18	185 4	73 36	174 26	36 19	134 52
90 − C S....	85 12	83 49	84 25	86 22	87 0	86 2

Difference in Longitude of the North and the South Poles.

Corona of July 29, 1878.......	101° 46′
" Jan. 1, 1889.......	100 53
" Dec. 22, 1889.......	98 33
Mean............	100° 24′

Mean Latitude of the North Pole.........	85° 32′
" " " South Pole.........	85° 24′

In all the coronas here presented the pole is on the earthward side of the plane of reference. Special attention should be called to Column θ_0 as it demonstrates the fact, without an exception, that the coronal rays spring from the Sun in a narrow belt, whose middle is about 34° from the coronal pole, the width being 10° to 15° in latitude. This phenomenon is such as to indicate that the terrestrial aurora had a similar historical origin, when the Earth was in a heated condition.

Having thus obtained one co-ordinate for the pole of the corona, namely c, we get the second by the angle between the trace of this pole and the trace of the sun's axis of rotation on same plane. Theoretically this should be very simple, and it would be so if the photograph were accurately oriented, but there is much to be desired in this respect, and it is hoped that the observers of coming eclipses will recognize its importance. I think that the most important inaccuracies of this work come in at this step, but I do not see how to remedy it at this time.

Diagrams are given showing the position angles of the poles of the Ecliptic, K, the Celestial Equator, E, the Sun's axis of rotation, S, and the Coronal pole, C, and side drawings of these points as existing on the surface of the sphere for each of the three Eclipses.

I have made two changes in the computation of July 29, 1878, the first in the value of M N by orienting the sun's axis relatively to the coronal axis 1° 30′ W. from N.; and the second in applying the value of M C with the opposite sign at the south pole as I had made a mistake in this respect.

The agreement of the difference of longitude, 100° 24′, shows that the poles rotate with the body of the Sun, in other words that the Corona itself rotates with the Sun, and must therefore be regarded as a fixed attachment to it. While the polar distance agrees for the two poles, they are twisted about in longitude so that the south pole precedes the north pole by about 100°, again reminding us of the condition of the earth so far as the location of the magnetic poles are concerned, in the latter case the difference of longitude being about 115°.

Compute the distance in a great circle between the north and south pole of the corona at the three eclipses from the respective latitudes and longitudes, with the view of strengthening the argument that the poles of the corona rotate with the body of the sun.

	(1)	(2)	(3)
a = North Polar distances (N)	4° 48′	5° 35′	3° 0′
b = " " " (S)	173 49	176 22	176 2
C = Difference in Longitude	101 46	100 53	98 33

$$k \sin K = \sin a \cos C$$

$$k \cos K = \cos a$$

$$\cos c = k \cos (b - K)$$

c = Great Circle distance	172° 59′	173° 56′	175° 23′
Mean	174 06′		

The result may be taken as testimony that the poles are fixed.

The length of the chord joining the north and south poles of the corona is

$$d = 2r \sin \tfrac{1}{2} c$$
$$= 1.99619\ r$$

If the radius of the sun r is taken as 866,500 miles, the axis of polarization in the body of the sun, to which the internal lines of force are parallel is 1,729,700 miles in length.

To find the Period of the Rotation of the Sun at the Coronal Poles, in Latitude 85°.5.

Eclipse 1, 1878, July 29, $9^h\ 23^m$ G. M. T. = 1878 · $210^d.39097$
" 2, 1889, Jan. 1, 9 16 " = 1889 · 1 .38611
" 3, 1889, Dec. 22, 0 15 " = 1889 · 356 .03681

	(1) to (2)	(1) to (3)	(2) to (3)
Eclipse intervals in Mean Solar days...........	3808.8144	4163.4651	354.6507
Assumed Number of Revolutions.............	Revolutions. 138	Revolutions. 151	Revolutions. 12
	+349°.85	+311°.40	+312°.55
	50029°.85	54671°.40	4641°.55
Mean Daily Motion.....	13°.1353	13°.1312	13°.0876

These data should be given equal weights for the three eclipses, as the conditions are practically the same in each. Adopting equations of the form:

$$\theta\ (t_1 - t) = \alpha$$
$$\theta\ (t_2 - t) = \alpha + \alpha_1$$
$$\theta\ (t_3 - t) = \alpha + \alpha_2$$

in which t is the epoch 1878.0, t_1, t_2 and t_3, the epochs of the three eclipses respectively, α the sidereal change in longtitude from t to t_1, and θ the mean daily motion in longitude, α and θ being the unknown quantities: The equations of condition are,

$$210.3910\ \theta - \alpha = 0$$
$$4019.2054\ \theta - \alpha - 50029.85 = 0$$
$$4373.8561\ \theta - \alpha - 54671.40 = 0$$

The normal equations are,

$$35328877.\ \theta - 8603.46\ \alpha - 440205067,$$
$$-\ 8603.5\ \theta + 3.\ \alpha = 104701$$

and the solution is,

$$\theta = 13^\circ.13307 = 13^\circ\ 7'\ 59''$$
$$\alpha = 2763^\circ.0$$

The equivalent Sidereal period is $27^{d}.41171 = 27^{d}\ 9^{h}\ 52^{m}\ 52^{s}$.
" " Synodic " $29.63580 = 29\ 15\ 15\ 33$.

If we compute the longitude of the coronal poles for 1878.0 as an epoch, we find from the three eclipses,

1878, July 29	200.3	302.1
1889, Jan. 1	209.1	310.0
1889, Dec. 22	198.1	292.7
Mean	201.2	301.6
Difference	104°.4	

These data, namely,

Longitude of North Coronal Pole for 1878.0 referred to the ascending node of the sun's equator on the plane of the ecliptic	201°.2
Sidereal period of the sun's rotation at the coronal pole	$27^{d}.41171$
or mean daily motion in longitude	13°.13307

furnish us with elements for predicting the position of the poles, and in consequence that of the corona at any epoch.

We are therefore in possession of such data as will enable us to make predictions as to the position of the poles of the corona at any epoch, and in consequence the relative form of the corona at the time as seen from the earth. A close comparison of a model with several photographs of recent eclipses displays a gratifying agreement in the details, and we hope to carry our study further in this direction.

The model also serves to strengthen the conviction that the sun-spots are probably formed by the descent of material from the extremities of the coronal streamers, in a vertical direction upon the sun. The circulation of the solar currents would therefore be, outwards along the coronal curves, under the law of repulsion inversely as the square of the distance, at the extremities of which a change in the physical condition takes place, by cooling or otherwise; then a return to the sun by the law of gravitation, the attraction being inversely as the square of the distance; and finally a slow drift of the solar surface towards the poles as already known to exist. This alternation of condition, by which the same matter is now repulsive and again attractive, seems to be a plausible explanation not only of this phenomenon but also of some other facts of solar physics.

The corona of Dec. 22, 1889, brings out an important circumstance. The originating belt seems to be somewhat nearer the poles than in the other coronas. If this shows that the belt moves up and down on the sun through a few degrees, we should remember that the extremities of the streamers, in consequence of the peculiar formation of the curves, will rise and fall to a greater extent, and the resultant parallels of the sun-spots will be modified in a similar manner. This accounts so well for the observed periodic changes in latitude for the spots, that it will be proper to investigate the question as far as possible.

The location of the coronal poles on one quadrant of the sun's surface will be the means of intensifying the forces that emanate from it on one side, and hence some color is given to those studies of terrestrial phenomena that point to the existence of a 27-day period, in response to the sun's rotation.

This analysis of the problem excludes all theories that ascribe the origin of the corona to extra-solar influences. We are not, however, in a position to say that the sun is magnetic because the coronal lines are similar to those surrounding a spherical magnet; nor that it is electrical, for the same reason. These phenomena are simply manifestations of the operations of the inverse of NEWTON'S Law, namely: repulsion in place of attraction. When matter attracts there is a center of attraction and of figure; when it repels, there are formed two poles of repulsion, and the body is polarized along an axis. If a name must be given to this theory of the corona, it will be more satisfactory to regard it as the *polarization theory of the solar corona.*

(SIXTH) AWARD OF THE DONOHOE COMET MEDAL.

The Comet Medal of the Astronomical Society of the Pacific has been awarded to E. E. BARNARD, Astronomer of the Lick Observatory, for his discovery of a Comet at 16 hours G. M. T., March 29, 1891. This is the fifteenth comet discovered by Mr. BARNARD.

The Committee on the Comet Medal,

EDWARD S. HOLDEN,
J. M. SCHAEBERLE,
CHARLES BURCKHALTER.